Development of the Great Lakes Ice-circulation Model: Application to Lake Erie in 2003-2004

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GOAL

To simulate ice and water circulation in Lake Erie over a yearly cycle, a Great Lakes Ice-circulation Model (GLIM) was developed by applying a Coupled Ice-Ocean Model (CIOM) with a 2-km resolution grid. The hourly surface wind stress and thermodynamic forcings for input into the GLIM are derived from meteorological measurements interpolated onto the 2-km model grids. The seasonal cycles for ice concentration, thickness, velocity, and other variables are well reproduced in the 2003/04 ice season. Satellite measurements of ice cover were used to validate GLIM with a mean bias deviation (MBD) of 7.4%. The seasonal cycle for lake surface temperature is well reproduced in comparison to the satellite measurements with a MBD of 1.5%. Additional sensitivity experiments further confirm the important impacts of ice cover on lake water temperature and water level variations. Furthermore, a period including an extreme cooling (due to a cold air outbreak) and an extreme warming event in February 2004 was examined to test GLIM's response to rapidly-changing synoptic forcing.

The goal of GLIM development is to add ice forecasts to an existing nowcast/forecast system in the Great Lakes. In addition, GLIM will also be used to test hypotheses related to lake ice dynamics and climate change.

Science Behind Forecasts

The Great Lakes Coastal Forecasting System (GLCFS) presently predicts lake water circulation, temperature, and surface waves (http://www.glerl/noaa.gov/GLCFS). Since it currently does not have a lake-ice component, empirical methods have been used to keep the system running over the winter. Wave forecasts also must be modified, as ice cover dampens surface waves significantly during winter. Thus, it is inadequate to use only a circulation model to investigate hydrodynamics and thermodynamics when lake ice is present. The increasing need for predicting lake ice for navigation, weather forecasting, rescue efforts, and ecosystem studies motivated us to develop a coupled ice-circulation model.

Atmospheric Forcing

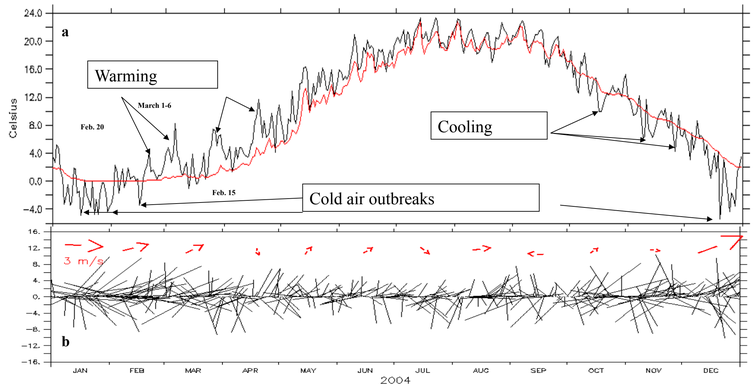

Figure 1. a) Hourly observed domain-averaged air (black) and surface water (red) temperature in 2004. b) Plot of daily mean wind speed vectors derived from the hourly data during 2004 at (80W, 42N), with monthly mean wind vectors (in red).

Model-Data Comparison

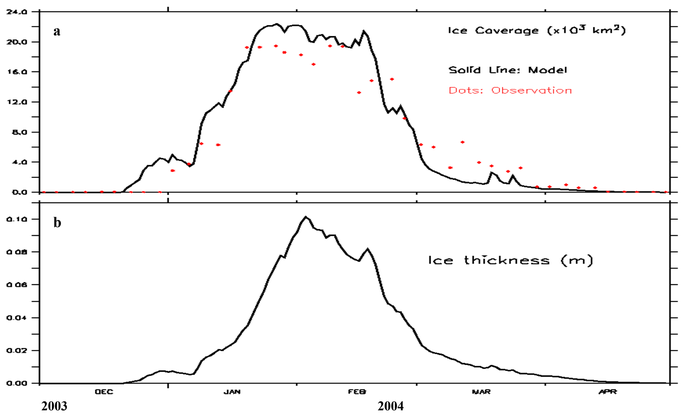

Figure 2. a) The GLIM-simulated ice area (solid, in km) and satellite-measured ice area (dots). b) Simulated domain-averaged ice thickness (in meters) from December 1, 2003 to April 30, 2004.

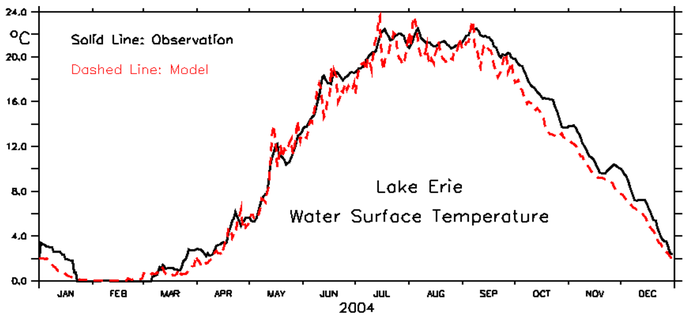

Figure 3. Temporal (daily) comparison of the domain-averaged LST between the GLIM simulation (dashed/red) and AVHRR measurement (solid/black) in 2004 (Units: C).

Model-simulated

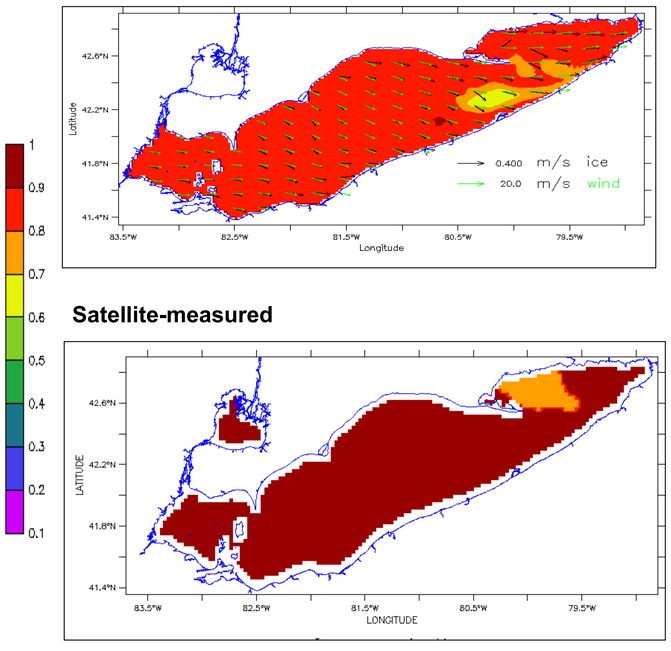

Figure 4. GLIM-simulated ice concentration vs. satellite Measurements.

Sensitivity Study: Ice dampens waves

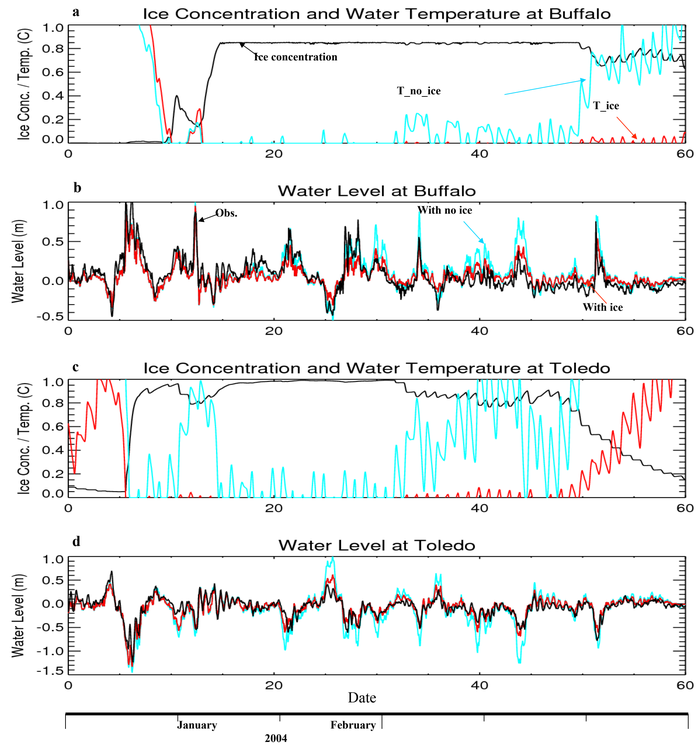

Figure 5. a) The GLIM-simulated ice concentration (black), surface water temperature with ice (red), and with no ice (green) at Buffalo. b) GLIM-simulated water level variations with ice (red) and with no ice (green) with comparison to the measurement (black). c) same as a), except at Toledo. d) same as b) except at Toledo. The start date is January 1, 2004. The means of the observed water levels were removed in the comparison.

Users

- USCG
- Shipping companies
- Universities
- National Weather Service
- State and Federal governments
- Public
- Media
- Congressional representatives

Status

GLIM was developed and validated against satellite measurements for an ice season 2003-2004.

GLIM was tested to be incorporated into the GLERL's Great Lakes Coastal Forecasting System for the ice season 2009-2010.

GLIM will be run for the period 1990 to present to investigate the interannual variability of lake ice and its response to the changing climate.